ORM for RHIC

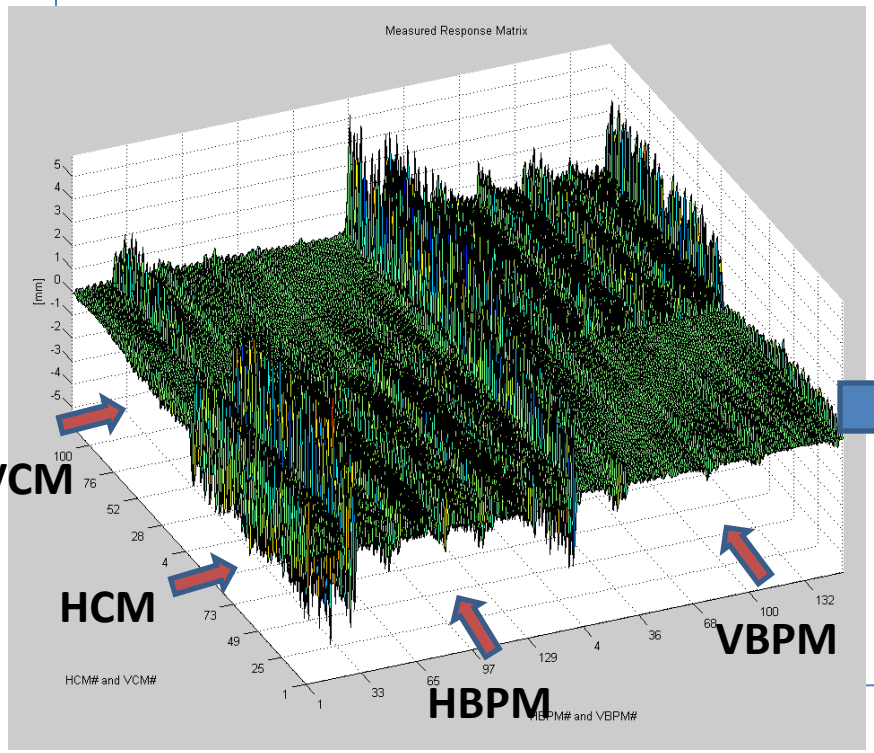
Orbit Response Matrix Analysis to Correct Linear Optics

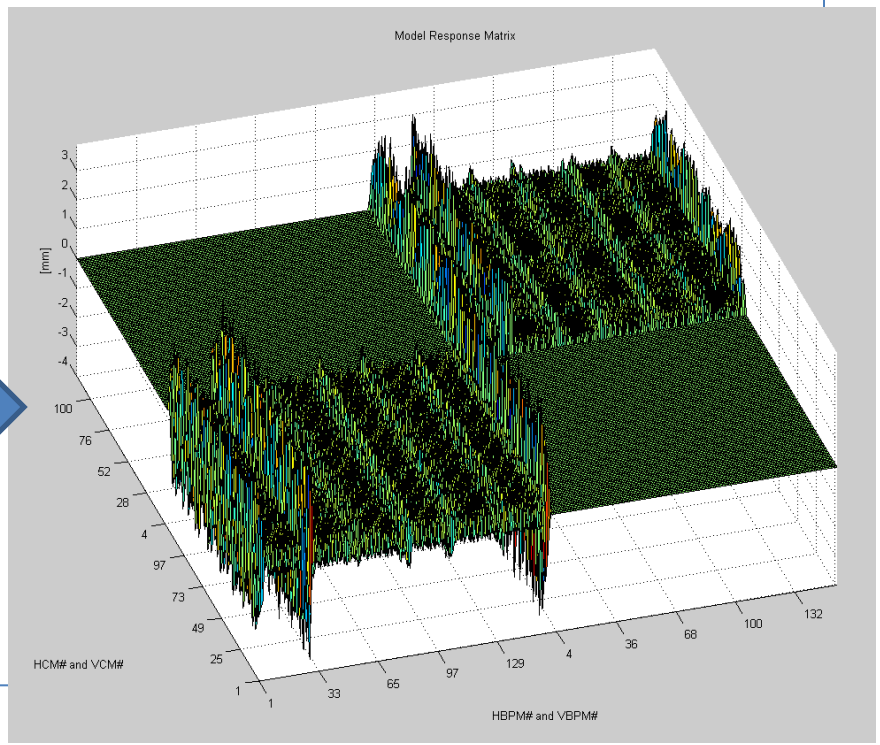
2011 APEX Workshop

December 8, 2011 | Tasha Summers

The Goal of ORM

- **Find and correct errors in storage ring linear optics**
- Compare a measured orbit response matrix to the model
  - Fit parameters in model are adjusted until it matches measurement
  - Find BPM and corrector gains, quadrupole strengths





Generating Data

Generate list of correctors (117 per plane in each ring)

– calculate size of kick to get maximum response in arcs (1 mm)

Measure Horizontal and Vertical planes separately

- one plane in both Blue and Yellow rings can be done simultaneously

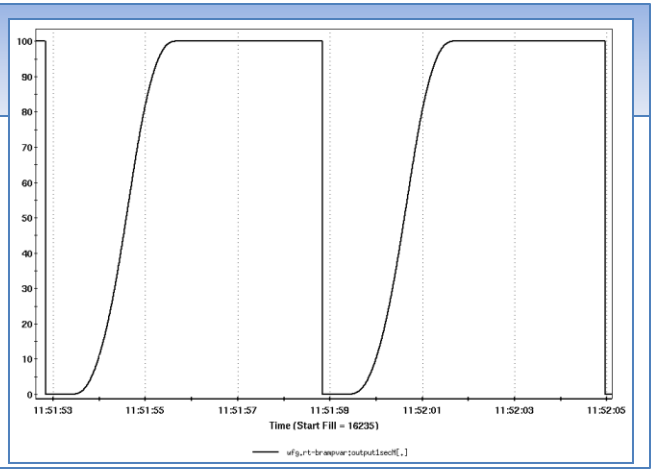
Old Method

- 2 hour measurement

```
]#!/bin/tcsh -f
#############################################################################
./orm.pl bi1-th3 yo1-th2 0.00774390321712892 0.00861864028163694
./orm.pl bi1-th5 yo1-th4 0.0159724845810633 0.0239260469060398
./orm.pl bi1-th7 yo1-th6 0.0206332325894713 0.0222427719537938
./orm.pl bi1-th9 yo1-th8 0.0203054161524584 0.0208503309285232
./orm.pl bi1-th11 yo1-th10 0.020621230686861 0.0204661661572301
```

New Method

- 50 minute measurement
  - wfgman is faster
- Limited by PS ramp rate and wait for new orbit data

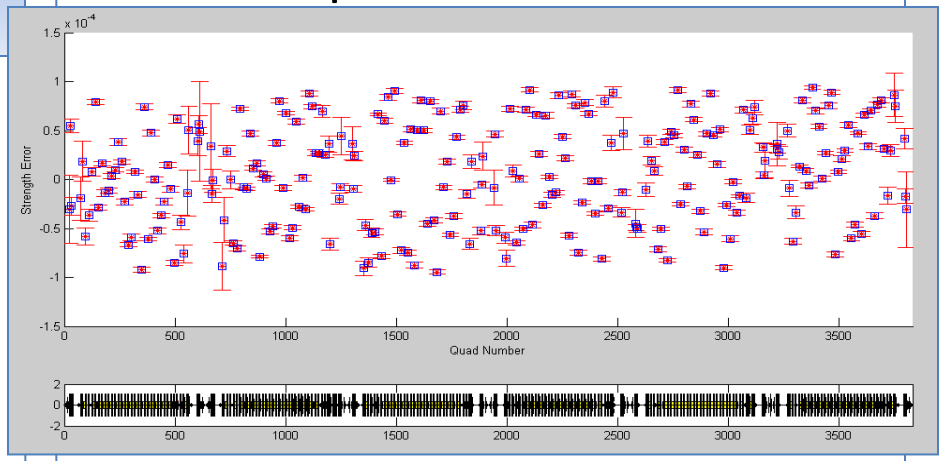


Simulation Proof of Principal

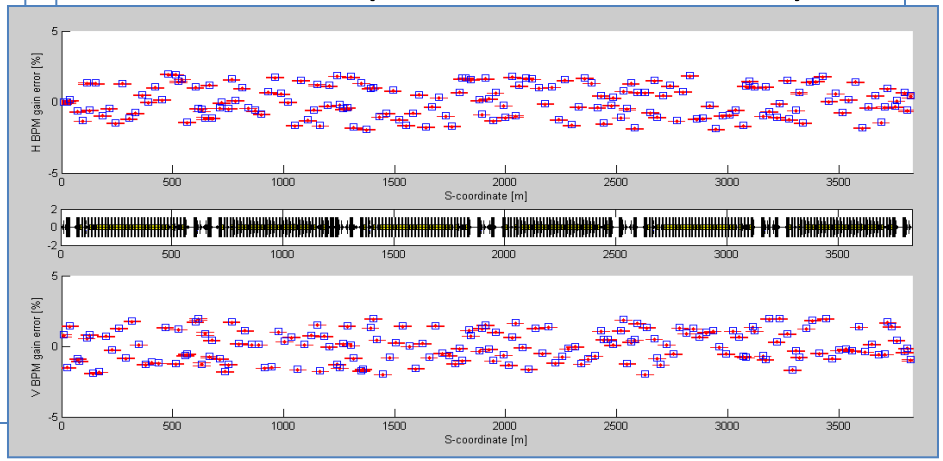
Au102 Blue Store (Jan 2010)

- Random ± 0.1 % Quad Errors With ± 2% BPM and Corrector Gain Errors
- No coupling
- 795 total singular values 793 used in fit
  - 315 BPMS
  - 234 correctors
  - 246 quads
- Simulation converged perfectly after 5 iterations
- No problem resolving errors in the triplet quads

- Quadrupole fits:



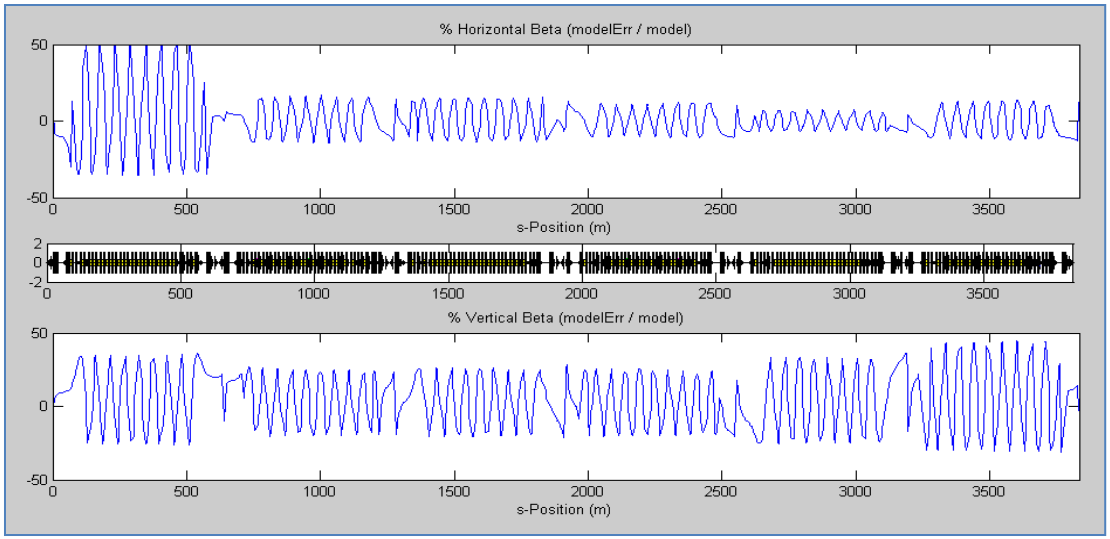
- BPM fits (correctors similar):



Simulation Proof of Principal

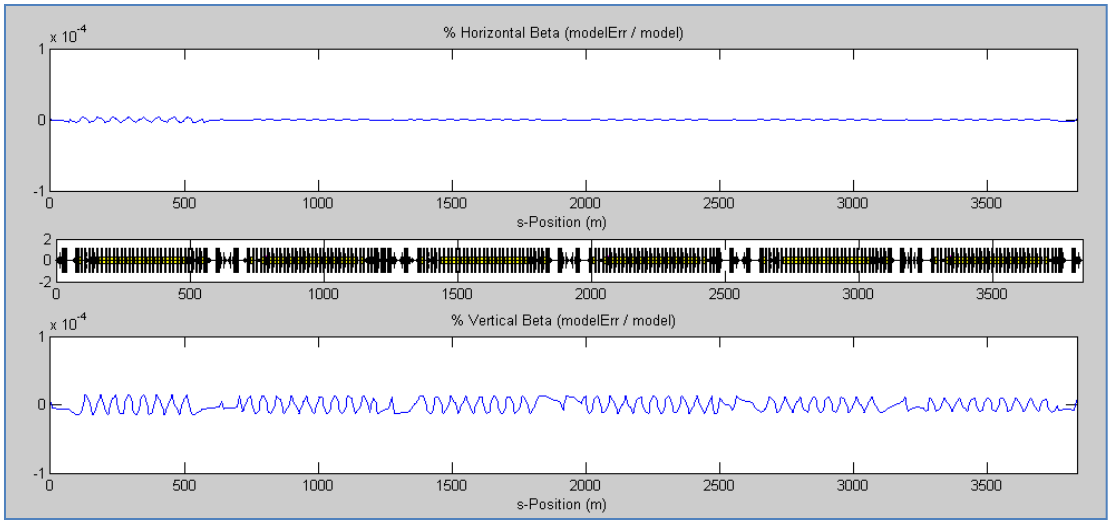
Initial Beta Beat

Scale ± 50%



5th Iteration

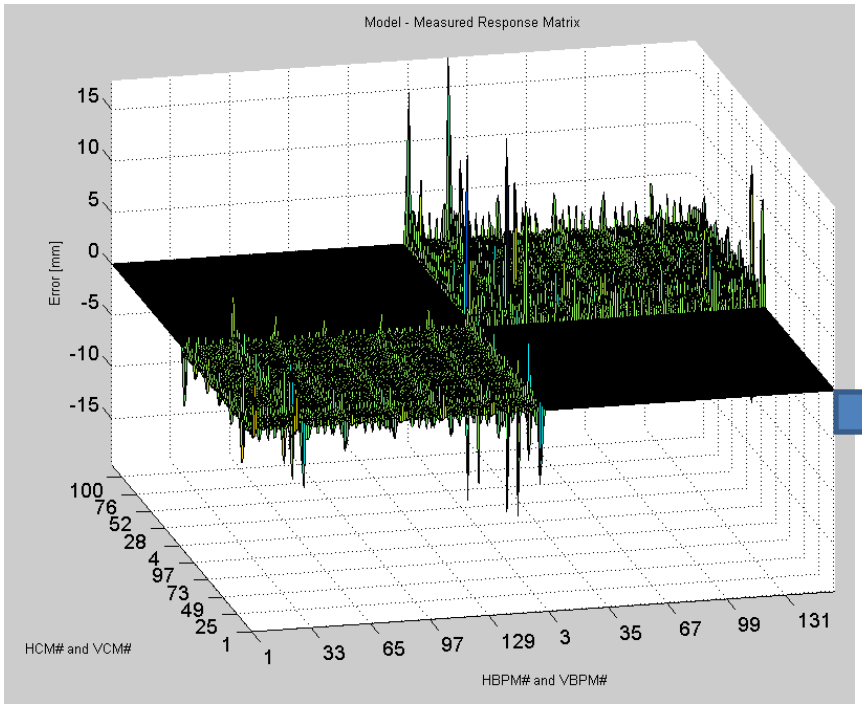
Scale ± 0.0001%

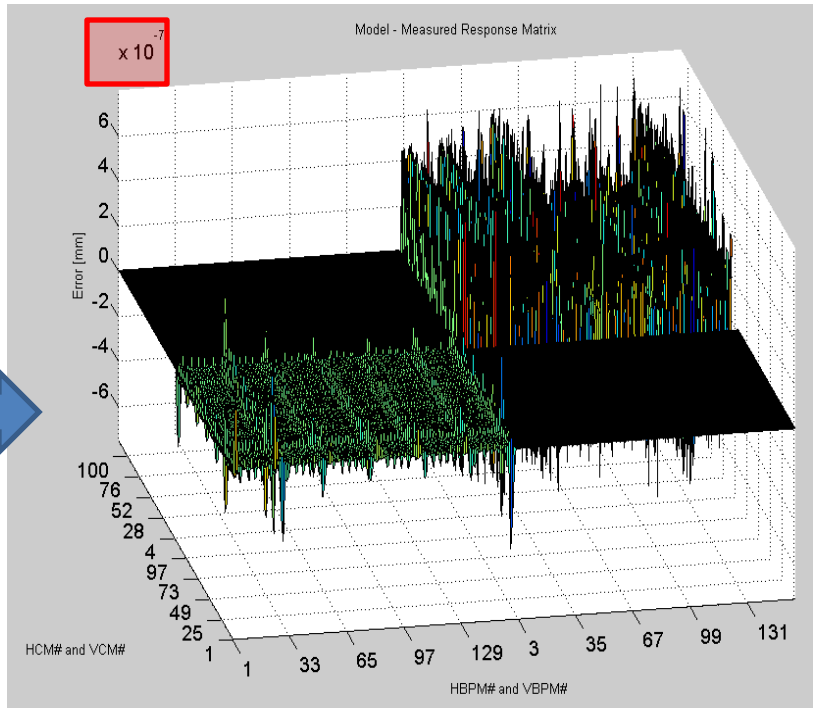


Simulation Proof of Principal

5 Iterations (10 minutes)

Fit all Quad, Corrector and BPM errors using 793 out of 795 singular values

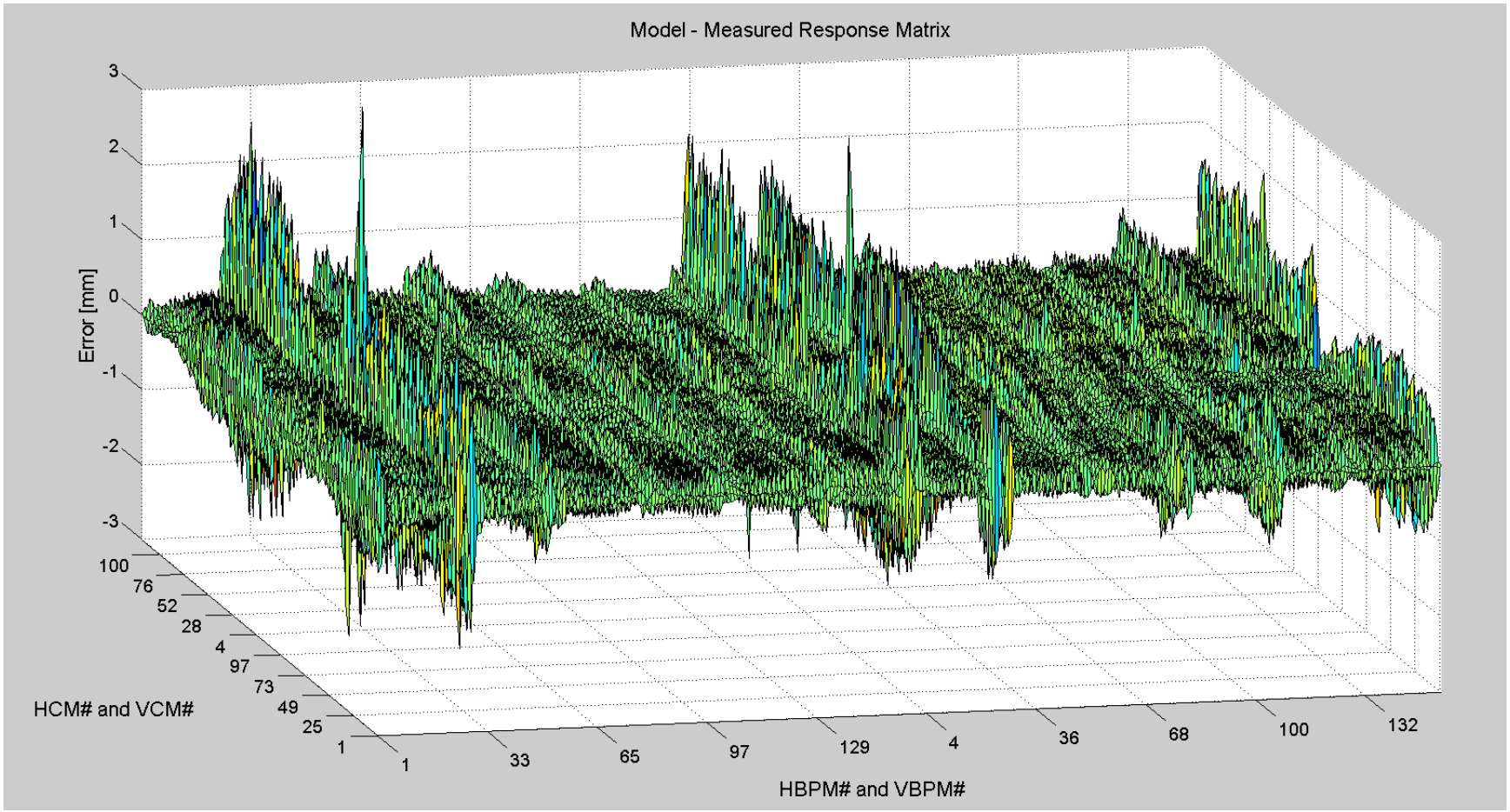




LOCO works perfectly with simulated errors for Au102 store model

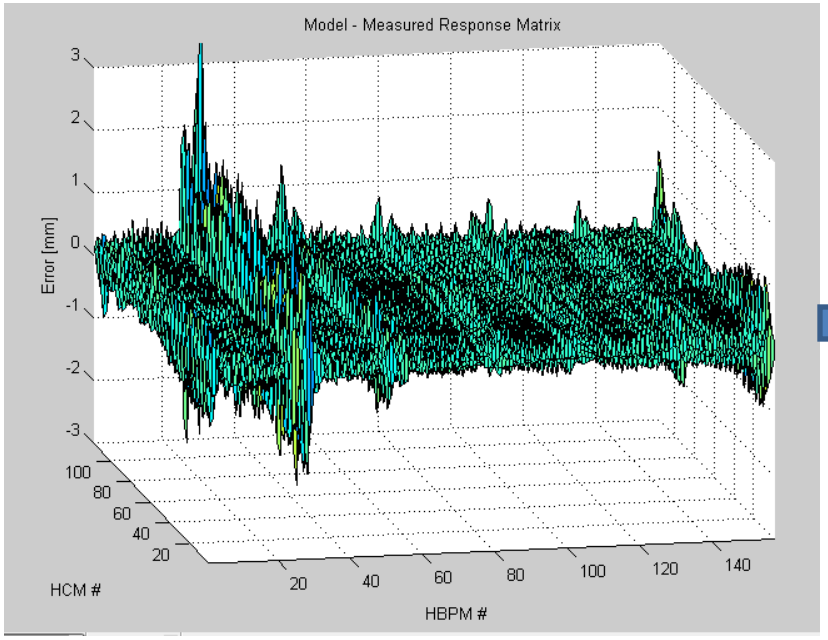
Au102 Measurement

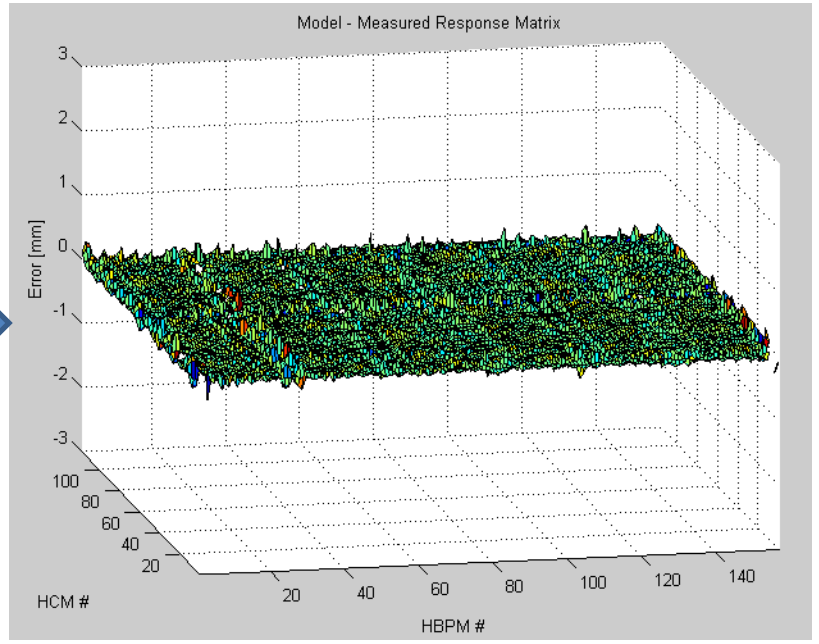
Au102 Blue Store Jan 2010 – Initial Response Matrix Difference



Au102 Measurement

- Fit Insertion Quads – 3 iterations
- Difference between model and measured matrices is much reduced
- Below shows HCM -> HBPM quadrant , vertical is similar



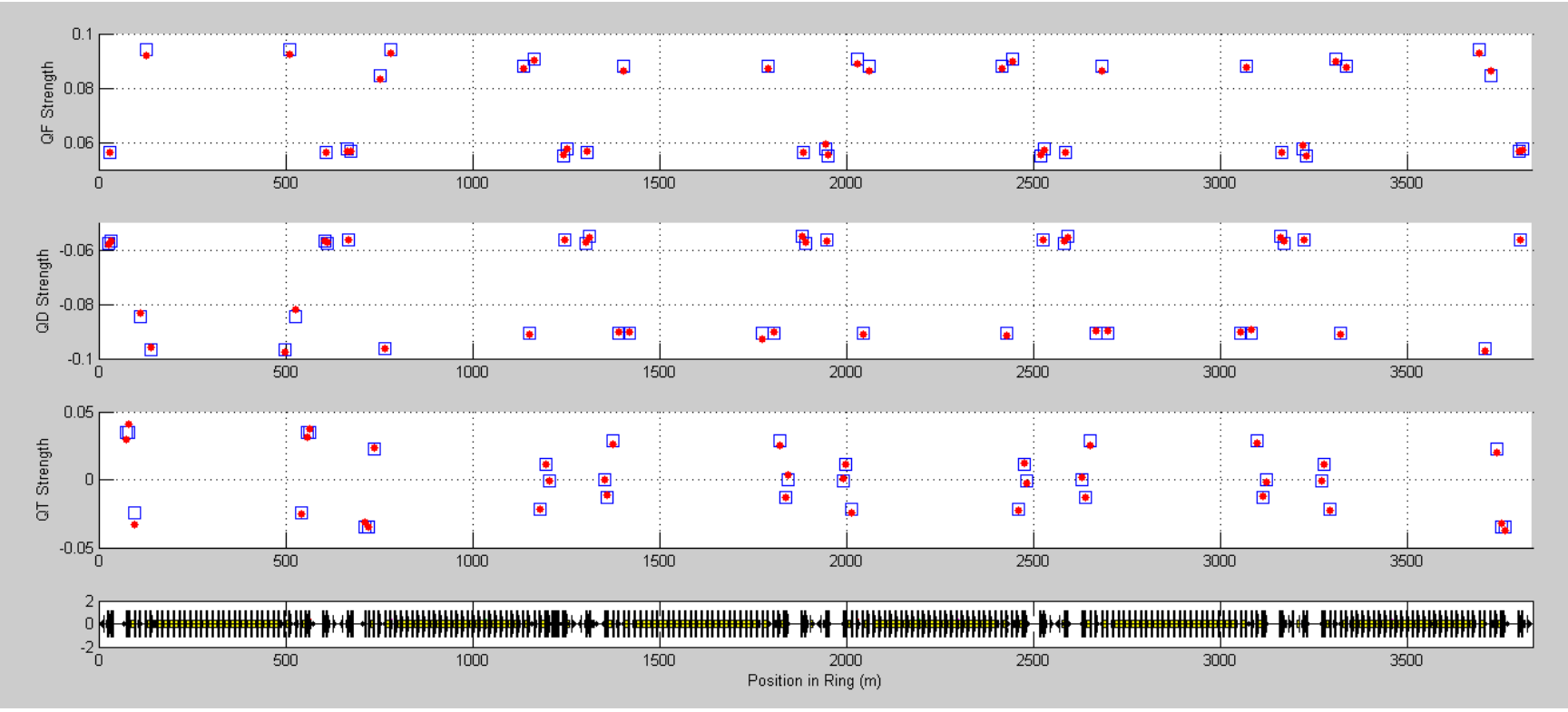


Au102 Measurement

Fitting Quads 1-9 QF/QD/Qtrim

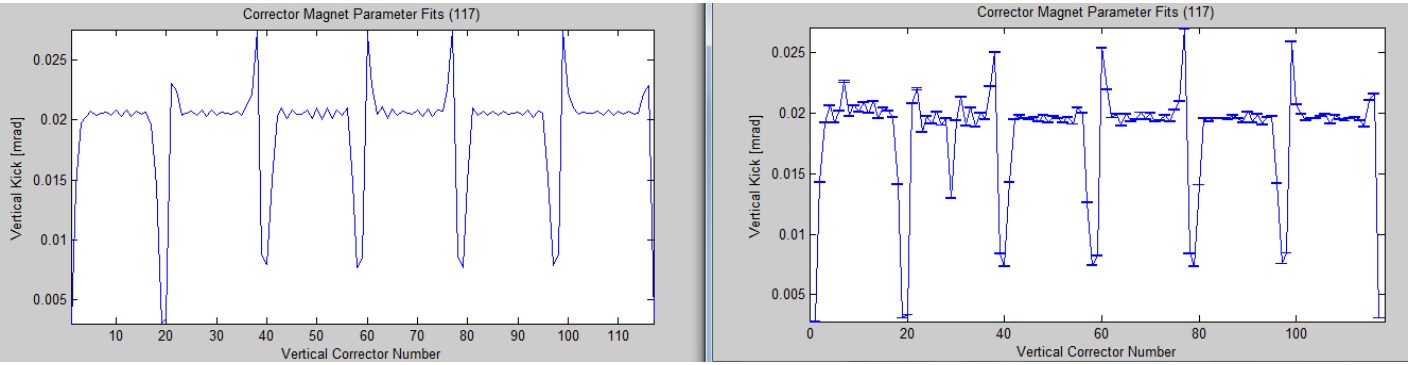
3 iterations reduces χ^2/d.o.f. from 167 to 16.4

Blue squares are initial strengths from online model, red dots are fits



Au102 Measurement

- Fitting SQ3s: having trouble fitting these (work in progress)
  - Hope with new local coupling correction at IRs this will be more manageable (should be better with small β* at injection as well)
- Fitting Corrector gains: all within a few percent
  except bi8-tv20 seems to be 40% low



- Fitting BPM gains: so far, solution diverges when added (also work in progress)

Sample Experiment

Machine and Time Requirements

- First measurement at injection
- Nominal bunch intensity, corrected tune & orbit
- ~ 1 hour setup and measurement (python scripts)
- Best case time to analyze: 30 minutes?
  - Matlab LOCO analysis:
    - get quad delta strengths (insertion QF/QD & SQ3)
      - » load into machine (python scripts)
    - get bpm and corrector gain factors (use for re-measurement)
- Re-measure response matrix to see if correction worked
- Measurements at store only if satisfied with results at injection

Summary

- Measurement will take less than half the time it used to
- Have python scripts (nearly) in place to do measurement and automatically log all relevant data (Al Marusic)
- More experience with setting up model for comparison – getting good results with simulation
- Scripts (Matlab and Python) are being developed to apply corrections quickly so that a new orbit response can be taken
  - This can be analyzed offline to verify correction or try find what failed
- The machine state can be reverted by loading saved file from RampEditor.